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Short Report

Infrared tympanic thermography as a substitute for a probe in the evaluation of ear temperature for post-mortem interval determination: A pilot study

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ABSTRACT

Reported methods which have been used to measure tympanic temperatures on cadavers up to now are quite invasive. They involve the use of a probe which can perforate the tympanic membrane and frequently causes bleeding from the ear. For this reason a non traumatic method for estimating tympanic temperature should be applied. Infrared tympanic thermometry seems to be a plausible option. Reliability of infrared tympanic thermometry (ITT) has been largely assessed on living individuals but only one author up to now has assessed its applicability for post-mortem interval determination. Thus the authors set out to test the difference between ear temperatures taken with a probe vs. ITT, differences between left and right ear and reproducibility of measurements of ITT. The aim of the study was to verify whether ITT could be a plausible option for measuring ear temperature for PMI estimation. Ear temperatures were taken on 25 cadavers (15 males, 10 females). Temperatures were taken alternately by similarly trained personnel by two technical methods (Checktemp 1 thermocouple probe and First Temp Genius infrared thermometer) for a total of 93 measurements. Statistical analysis of the data was performed using SAS statistical software. The range of temperature measured was from 20 to 28 °C, statistical analysis revealed no differences within the two technical methods, both for right and left ear (ITT: 22.33 ± 0.35 vs. probe: 23.08 ± 0.25; $P = 0.087$). The study shows the ITT method can be considered as a possible alternative to the probe for measuring ear temperative and further studies should be considered.

1. Introduction

Determination of the post-mortem interval (PMI) is one of the most crucial and difficult issues to confront, even in the very early post mortem interval. Scientific literature offers numerous publications on the cooling rates of different parts of the body (brain, skin, rectum, liver), along with the study of muscle contraction, gastric emptying and vitreous and CSF K+. A thorough review of these methods has been given in the fairly recent book edited by Knight.[14] Many studies have indeed been performed in order to determine algorithms by which to establish PMI of bodies found in "air" ambient, in other words found in the open environment, be it indoors or outdoors. They reached a climax in the numerous works of Henssge's group[11,8–10,13] who attained rules and nomograms by which to calculate PMI and which are applicable to numerous situations. Rectal cooling seems to be the most thoroughly explored method. Several authors have proven however that cerebral temperature (although its measurement implies fracturing the sphenoidal component of the orbit, or, alternatively, the ethmoid bone) decreases after death in an exponential manner, without plateaus, and is therefore most sensitive and accurate, particularly in the early post mortem period.[12,19] Recently Al Alousi et al.[1] compared the cooling curves of liver, brain and rectum. Results showed that slopes vary throughout the monitoring period, however the initial temperature plateau is found on average in 22% of all cooling curves, with the plateau incidence being highest in rectal curves. Thus cerebral temperature seems to be a more precise tool for early PMI estimation, and does not seem to be affected by body weight, clothing or physical activity. Extensive work on postmortem interval performed by Baccino and collabora-

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tors[2] studied the temperature in the deep auditory canal/tympanic membrane, and found results to be more accurate than those previously obtained. The temperature of the tympanic membrane has been shown to be closely correlated to that of the hypothalamus[4,16] and therefore can be considered equal (or very close) to the core temperature of the head. In their studies,[2] demonstrated that ear temperature methods gave more accurate results than all three methods (Henssge's nomogram, Rule of thumb 1 and 2, and K+ concentration in vitreous and CSF), particularly when ambient temperature was over 15 °C and for post-mortem delays up to 20 h. It is also obvious that taking tympanic temperature is more user friendly and quick and can be done bilaterally.

In many ways, it is surprising that workers in the field have concentrated more on the rectum, since, intuitively, the head can be considered as an "independently" cooling system, with, perhaps, far less variables affecting it. Measuring body temperature from the head has indeed obvious advantages as regards accuracy and it bypasses the issue of contamination in suspected cases of sexual violence (unlike measuring at the rectum). Furthermore the temperature plateau is avoided (or greatly reduced) because the small globe-shaped head cools uniformly, with no significant delay in establishing a temperature gradient.[21] The numerous studies performed indicate that cerebral and tympanic temperatures are, per se, more accurate and precise indicators within the early post-mortem interval. Since tympanic temperature closely reflects cerebral temperature but can be taken in a far more simple manner, it seems reasonable that for future studies tympanic temperature should be taken into consideration. However, reported methods which have been used to measure tympanic temperatures on cadavers up to now are quite invasive. They involve the use of a probe which usually perforates the tympanic membrane and frequently causes bleeding from the ear. Although it has been reported that this does not alter the actual tympanic temperature (as related to cerebral temperature),[23,3] perforation and bleeding have two major setbacks. The first one consists in the fact that this will create artifactual trauma which will be perceived at autopsy. Secondly, in many European countries PMI estimation at times is required for necroscopic purposes, since an autopsy has not been requested and time of death must be evaluated only for certification purposes. For this reason a non traumatic method for estimating tympanic temperature should be applied.

Infrared tympanic thermometry seems to be a plausible option. ITT has documented benefits including speed, ease of use, non invasiveness. These assets have supported their use in emergency departments and intensive care units.

Reliability of infrared tympanic thermometry (ITT) has been largely assessed on living individuals but never on cadavers. A study performed comparing rectal and pulmonary artery thermometers, compared to ITT, showed that these thermometers were, on average, 0.3684° lower.[15,5] Studies comparing infrared tympanic thermometry to mercury rectal thermometers on the other hand showed large differences for the detection of fever[26]; another clinical study comparing thermocouples and infrared thermometers showed correlation coefficients of 0.6 circa[17]; English researchers have also verified that ITT does not show sufficient agreement with other established methods of temperature measurement.[6] However, always in the clinical setting, some discussion exists, since other researchers have shown that infrared aural canal thermometers are moderately accurate and precise.[22,7,20] As far as reproducibility is concerned a French study showed limits of agreement between both ears of −1/+1 °C and −0.6, +0.7°C for two consecutive measurements in the right ear.[18]

Nonetheless, in the forensic setting, very little is known as regards both reproducibility and correspondence with tympanic temperature measured with probes. The only studies performed up to now have been those of Rutty.[24,25] Rutty set out to verify on canine and human models, whether temperature can be recorded form the external auditory canal and can be used for PMI estimation. His results show that infrared thermometers can be used to record temperature from the external auditory canal, that it is generally lower than that of the rectum and that the most suitable algorithms applicable may be the Henssge nomogram for the brain or that of Baccino et al. (mentioned above).

Thus the authors set out to verify Rutty's results and test the difference between ear temperatures taken with a probe vs. ITT, differences between left and right ear and reproducibility of measurements of ITT. The aim of the study was to verify whether ITT could be a plausible option for measuring ear temperature for PMI estimation.

2. Materials and methods

Ear temperatures were taken on 25 cadavers which reached the Medico-Legal Institute of Milano, at different time intervals. Temperatures were taken alternately by similarly trained personnel via two technical methods: with a Checktemp 1 thermocouple probe (probe) and with a First Temp Genius infrared thermometer (ITT). For most cadavers, between two and eight measurements were taken at set intervals usually between 10 h and 20 h from their arrival at the morgue, for a total of 89 measurements. Temperatures were all included between 20 °C and 28 °C. According to Italian Police Mortuary regulation, non-putrefied or mutilated cadavers must remain in observation at 14 °C for 24 h.

At each set time, the following six measurements were taken: (1) probe at the left ear; (2) probe at the right ear; (3) ITT at the left ear; (4) after 1 min a second measurement of ITT at the left ear (by extracting and reinserting the probe); (5) ITT at the right ear; (6) after 1 min a second measurement of ITT at the right ear (by extracting and reinserting the probe). Two measurements were always taken for ITT to check reproducibility, since the insertion of the tip of the thermometer may pose some difficulty and may differ from time to time.

Statistical analysis of the data was performed using SAS statistical software (SAS Institute Inc. (2000), Version 8 2000 SAS Institute Cary, NC). Data were analyzed using one-way ANOVA, where the two different types of method, i.e. the probe or the infrared thermometer were the main factors. Values from each cadaver were considered as the experimental unit of all response variables. Set time was not included in the model because it was not always statistically different. Differences between means were considered significant at $P \leqslant 0.05$.

3. Results and conclusions

Results are presented in Fig. 1. Ear temperatures (left and right ears) were not significantly influenced by the technical method

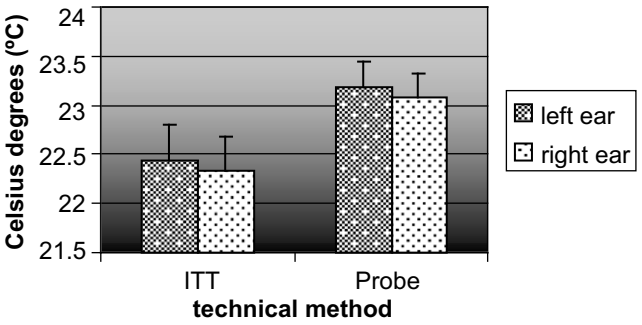

Fig. 1. Left and right ear temperatures (°C) of cadavers. Results are reported as mean temperature ± SEM. Significant effects are not noted ($P > 0.05$).

used (ITT vs. probe). Ear temperatures revealed to be similar with ITT and probe method in both the ears ($P > 0.05$).

The range of temperature measured was contained within 20–28 °C, statistical analysis revealed no differences within the two technical methods, both for right (ITT: 22.43 ± 0.37 vs. probe: 23.18 ± 0.26; $P = 0.108$) and left ear (ITT: 22.33 ± 0.35 vs. probe: 23.08 ± 0.25; $P = 0.087$). Data thus seem to reveal that ITT method can be considered equivalent for measuring ear temperature although applicability to larger temperature intervals must be performed.

One should keep in mind in fact that infrared thermometry functions according to manufacturer's recommendations and not below certain ambient temperatures. This limits the application of the method. The study appears to confirm Rutty's results, i.e. that ear temperature can be reliably taken by ITT and that side does not have a great significance if the body is in a prone position. It should be stressed that further research is necessary.

Conflict of Interest

None declared.

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Ethical approval

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References

1. Al-Alousi LM. A study of the shape of the post-mortem cooling curve in 117 forensic cases. *Forensic Sci Int* 2002;**125**:237–44.
2. Baccino E, De Saint Martin L, Schuliar Y, Guilloteau P, Le Rhun M, Motin JF, et al. Outer ear temperature and time of death. *Forensic Sci Int* 1996;**83**:133–46.
3. Baccino E. Response to Dr. Rutty's letter re: outer ear temperature and time of death. *Forensic Sci Int* 1997;**87**:173.
4. Bezinger TH, Taylor GW. *Temperature: Its Measurement and Control in Science and Industry*, 111. New York: Rheinhold; 1963.
5. Cattaneo CG, Frank SM, Hesel TW, El-Rahmany HK, Kim LJ, Tran KM. The accuracy and precision of body temperature monitoring methods during regional and general anesthesia. *Anesth Analg* 2000;**90**(4):938–45.
6. Craig JV, Lancaster GA, Taylor S, Williamson PR, Smyth RL. Infrared ear thermometry compared with rectal thermometry in children: a systematic review. *Lancet* 2002;**360**(9333):603–9.
7. Harasawa K, Kemmotsu O, Mayumi T, Kawano Y. Comparison of tympanic, esophageal and blood temperatures during mild hypothermic cardiopulmonary bypass: a study using infrared emission detection tympanic thermometer. *J Clin Monit* 1997;**13**(1):19–24.
8. Henssge C. Death time estimation in case work: I the rectal temperature time of death nomogram. *Forensic Sci Int* 1988;**38**:209–36.
9. Henssge C, Madea B, Gallenkemper E. Death time estimation in case work: II integration of different methods. *Forensic Sci Int* 1988;**39**:77–87.
10. Henssge C. Rectal temperature time of death nomogram: dependance of correctives factors on the body weight under stronger thermic insulation condition. *Forensic Sci Int* 1992;**54**:51–66.
11. Henssge C, Brinkmann B, Puschel K. Todeszeitbestimmung durch messung der rektaltemperatur bei wassersuspension der leiche. (Determnation of time of death by measuring the rectal temperature in corpses suspended in water). *Z Rechtsmed* 1984;**92**:255–76.
12. Henssge C, Beckmann F, Wischusen F, Brinkmann B. Determination of time of death by measuring central brain temperature. *Z Rechtsmed* 1984;**93**:1–22.
13. Henssge C. Temperature-based methods II. In: Henssge C, Knight B, Krompecher T, Madea B, Nokes L, editors. *The Estimation of the Time since Death in the Early Postmortem Period*. London: Arnold University Press; 2002. p. 60–1.
14. Henssge C, Knight B, Krompecher T, Madea B, Nokes L. *The Estimation of the Time since Death in the Early Postmortem Period*. London: Arnold University Press; 2002.
15. Hoffman C, Boyd M, Briere B, Loos F, Norton PJ. Evaluation of three brands of tympanic thermometer. *Can J Nurs Res* 1999;**31**(1):117–30.
16. Houdas Y, Guieu JD. *Distribution Thermique dans l'Organisme*. Paris: Simep ed.; 1977.
17. Imamura M, Matsukawa T, Ozaki M, Sessler DI, Nishiyama T, Kumazawa T. The accuracy and precision of four infrared aural canal thermometers during cardiac surgery. *Acta Anaesth Scand* 1998;**42**(10):1222–6.
18. Joly LM, Giraudeau B, Monchi M, Oswald AM. Is measurement of body temperature by infrared tympanic thermometry reproducible? *Ann Fr Anesth Reanim* 2001;**20**(10):833–7.
19. Joseph AEA, Schickele E. A general method for assessing factors controlling post mortem cooling. *J Forensic Sci* 1970;**15**:364–91.
20. Kawamura A, Matsukawa T, Ozaki M, Okuyama K, Ohkawa I, Kumazawa T. Use of modified infrared aural canal thermometers during cardiac surgery. *Masui* 2000;**49**(7):792–5.
21. Knight B, Nokes L. Temperature-based methods I. In: Henssge C, Knight B, Krompecher T, Madea B, Nokes L, editors. *The Estimation of the Time since Death in the Early Postmortem Period*. London: Arnold University Press; 2002. p. 29–31.
22. Matsukawa T, Ozaki M, Hanagata K, Iwashita H, Miyaji T, Kumazawa T. A comparison of four infrared rympanic thermometers with tympanic membrane temperatures measured by thermocouples. *Can J Anaesth* 1996;**43**(12):1224–8.
23. Rutty GN. Concerning the paper by Baccino et al. entitled: outer ear temperature and time of death. *Forensic Sci Int* 1997;**87**(2):171–3.
24. Rutty GN. The estimation of the time since death using temepratures recorder from the external auditory canal Part I: can a temperature be recorded and interpreted from this site. *Forensic Sci Med Pathol* 2005;**1**(1):41.
25. Rutty GN. The estimation of the time since death using temepratures recorder from the external auditory canal. Part II: using single temperatures from this site to estimate the time since death with consideration of environmental body factors that could affect the estimation. *Forensic Sci Med Pathol* 2005;**1**(2):113.
26. Valle PC, Kildhal-Andersen O, Steinvoll K. Infrared tympanic thermometry compared to mercury thermometers. *Tidsskr Nor Laegeforen* 2000;**120**(1):15–7.